Communication between architect and engineer in a creative environment

A glimpse of the mutual knowledge required for interdisciplinary design

Laurens Luyten

Sint-Lucas, School of Architecture, Brussels, Belgium
Chalmers, School of Architecture, Goteborg, Sweden

laurens.luyten@architectuur.sintlucas.wenk.be

Abstract. When architect and engineer work together as an interdisciplinary design team, creativity takes place through the knowledge of both disciplines, and not within a single discipline alone. This requires a rich communication. Therefore architect and engineer need to possess sufficient mutual knowledge on both disciplines. By examining four of my own projects as structural engineer, several communication characteristics for interdisciplinary design could be determined. They show that communication with a high level of discipline related abstraction enhances the interdisciplinary creativity.

Keywords. Interdisciplinary design; structural engineer; architect; communication; interdisciplinary knowledge.

Mutual interdisciplinary knowledge on architectural structure

Already in 1967 Engel was convinced that in order to design 'con-temporary' buildings, teamwork between experts in science and architecture is necessary (Engel and Rapson, 1967). Today it is common practice for architects and engineers to work together.

Structural engineer Ney states that engineers today are well equipped to dimension structures, but not to conceptualize them, and that architectural education is devoted to learning about research into shape, but that shape usually is conceived before considering structure (Strauven and Ney, 2005). So who takes care of designing the architectural structure[1]?

When making an architectural design, many criteria (e.g. budget, function, expression, environment, space quality) have to be taken into account. Structural stability is one of these criteria. Since the shape of the building is directly related to the structure which holds it together, the structural concept of the building is basically designed when the shape is designed. So if we want to take care of the architectural structure, we have to be conscious of the structural implications when designing the shape of the building. The search space[2] of design solutions for the architectural shape – and, as a consequence, for the structure – is still large at the beginning of the design process.

In creative design, opposed to routine design, it is important to keep this search space large while the design process evolves, to enable a maximum of creativity through the knowledge of all disciplines involved**: interdisciplinary design**. This is opposed to **intradisciplinary design**, when the creative design step is taken within a single discipline without taking into account any criteria of other disciplines.

A first step in keeping the search space large for interdisciplinary design to take place, is by having interdisciplinary collaboration in the beginning of the design process (opposed to late). A second step for a large search space can be established by

---

[1] Structural design in coherence with the architectural design.

[2] Search space or solution space, is a term used in mathematics, defining the range of possible solutions to a given problem.

keeping a range of design solutions from each individual discipline, rather than providing a single design solution (Lottaz et al, 2000). This range of solutions is related to the level of abstraction within the discipline: a disciplinary concept (e.g. hyperstatic beam) provides a wider range of design solutions than the single concrete solution (e.g. steel beam HEB200). In order to understand a range of solutions on a high level of abstraction, sufficient disciplinary knowledge is needed.

When architect and engineer[3] design the architectural and the structural shape together as an interdisciplinary team, they have to communicate. Their communication will only be successful if they possess the same 'system of thoughts'[4] (internal) and understand the same 'system of symbols'[5] (external) on this mutual ground of structural and architectural knowledge (Fauconnier, 1986). For now, I will call this mutual knowledge both actors have on both disciplines: mutual interdisciplinary knowledge (MIK). To be able to have a rich communication and to keep the search space large for an interdisciplinary design, both actors need sufficient MIK.

The aim of my research is by looking at the communication (system of symbols) between architect and engineer during interdisciplinary design, determine the characteristics of this MIK, upon which the system of thoughts is based. This MIK is an important element in the education of engineers and architects, and is a starting point for interdisciplinary collaboration improvement.

Previous studies on collaboration of architects and engineers

There is a consensus about the importance of having all experts in the AEC (Architecture, Engineering, Construction) domain work together early on in the design process, to come to a creative or innovative design where the different expertise are integrated (Quanjel and Zeiler, 2007; Quanjel et al, 2006). In order to create the right setting for this collaboration, research has been done on design management in the conceptual phase of the design process. Software has been developed to improve design efficiency and negotiation between different experts within the design team (Lottaz et al, 2000; Tunçer et al, 2000; Stouffs, 2000).

By developing a concept of the design process during the early phase, effort has been made to create a methodology for the interdisciplinary team of designers as a guidance during the design process (Austin et al, 1999; Steele et al, 2000; Quanjel et al, 2006).

Because each discipline within the AEC domain has its own concept and interpretation of the built object, the design model of the CAD systems as a tool for an interdisciplinary collaboration, must possess multiple representations according to these different concepts (Fruchter et al, 1996; Rosenman et al, 2005; Rosenman and Gero, 1996). When communicating with another discipline, the appropriate level of abstraction of the own representation must be chosen to get the intended message across without an overload of data (Zeiler and Quanjel; 2007).

Much of the above research deals with the conditions and methodology for an interdisciplinary collaboration in the AEC domain early in the design process. But in my view they say little about which MIK architects and engineers need to establish interdisciplinary creativity: which structural knowledge does the architect need and

---

[3] 'Architect' is used here as the expert in designing architectural shapes, 'engineer' as the expert in designing structure.
[4] Personal translation of the Dutch 'Gedachtensysteem',
[5] Personal translation of the Dutch 'Systeem van betekening'

which architectural knowledge the engineer? (Getting some art into science and some science into art).

Case studies on communication between architect and structural engineer

In order to understand more about the MIK needed for architect and engineer to have an interdisciplinary collaboration, I have elaborately examined four of my own projects as structural engineer with different architects. In cases one to three, the logbook of events was analysed and the architects were interviewed. In case four, the logbook and a videotaped meeting were analysed. These four projects I consider to have at some point an interdisciplinary creative design step. They are ordered from narrow to wide search space of design solutions, when the collaboration started.

Furthermore I am in the process of examining a still ongoing seminar with architecture students in their last year. In this seminar students are asked to design their own architecture office. Like practicing architects, they can get structural counseling from myself as engineer, but they have to use this counseling from the beginning of their design process. This enables me to determine the type of structural information needed at the beginning of the design process.

There is a difference in designing between expert designers and novice designers (Akin, 2002). Therefore I have categorized these cases according to the level of experience of the architect and also of the teamwork between the architect(s) and myself. (There is no category for the experience of the engineer, because in all these cases I was the engineer. I am a practicing structural engineer since 1993).

The other element of distinction I have used, is the moment of collaboration in the design process. When the collaboration occurs in the stage of preliminary design, I consider this early in the process (EP). When it occurs in the stage of the building proposal or later, I consider this late in the process (LP).

These categories were used as focus points in analysing the characteristics of the interdisciplinary design.

Case number	Architect			
	novice		expert	
Teamwork	LP	EP	LP	EP
novel	-	seminar	nr.3	nr.4
experienced	-	-	nr.1&2	-

Table 1
Categorisation of case studies (Collaboration Late (LP) or Early (EP) in the design Process).

In the majority of the projects I have done in my career, I am asked to design the structure when the overall architectural shape is designed and most materials of constructions are determined (**search space is narrow**). The architect conveys his project to me through two dimensional **(2D) representations** of the building (elevations, facades and cross sections on a scale of 1/50 or 1/100): these plans are made for **building approval** and have often a clear indication of the construction and structure of the building (e.g. materials and their dimensions). In some cases construction details are included on a scale of 1/10 (**low level of abstraction**). They are in black and white and give only a limited representation of the feel and touch of the building.

On the level of the overall shape of the building, the architect has made an important **intradisciplinary design** step: this shape is created by the architect alone and is basically not meant to be altered.

In general these plans give me the three dimensional (3D) space in which I can operate as engineer: into this space of materials (brick, concrete, steel, etc.) I have to fit the structure.

First I design a structural model that consists of the structural elements and their connection. This is the **intradisciplinary** creative part of my job. After designing the model, the structural elements are dimensioned through standardized calculations. If the dimensions do not fit into this material space given to me, I redesign the model to find a better fit. This is a cyclic process.

After I have done my structural study in general, I make up a structural plan for the architect. The given architectural ground plans are used as under layer upon which I draw the structural elements of the ceiling structure with their dimensions. These dimensions are in construction codes (e.g. HEB200, B 20/60). Sometimes hand drawn sketches of structural details are included to explain the construction method and position of the structural element. These **drawings contain very little structural knowledge**: it is a naïve representation of the shape of the structure (**low level of abstraction**).

Once this **2D structural draft** is faxed or e-mailed to the architect and after he studied it, we often discuss it on the **telephone**. Mostly to check if everything is understood and to see if there are still problems left. If the latter is the case, the problem often gets solved during this telephone meeting. In general there are **few face-to-face** meetings. Most meetings are via telephone: before the architect hands over his plans, sometimes during my study to consult the architect, and after the study is handed over.

When this stage is done the structure is designed and dimensioned. The next step is making up the execution plans for architecture and structure, which I do not consider to be important for examining within my research project.

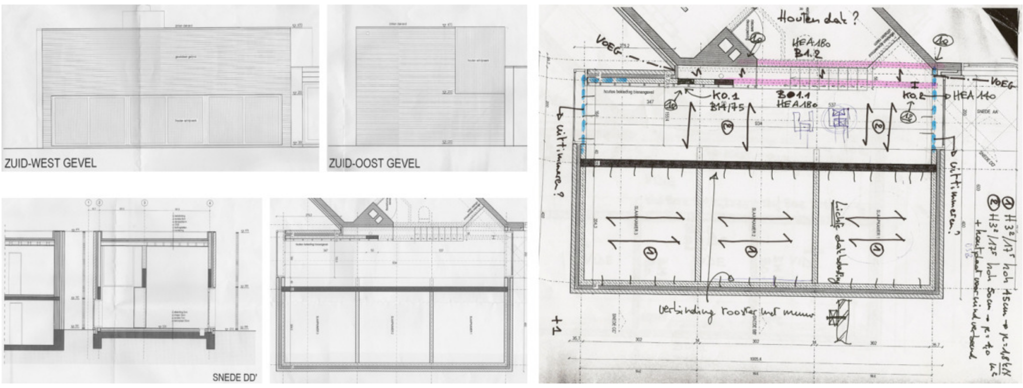

Figure 1 *copyright architectural plans: T. Van Mieghem*
Majority of the projects: (left) scans of the architectural plans; (right) scan of the structural draft.

These cases have a typical **intradisciplinary character**: first the architect designs the architectural shape and then the engineer designs a structure that fits into this shape. The **collaboration starts late in the design process.** There is **little direct interpersonal contact**. Questions and answers are directed towards **a single concrete design solution** per discipline: a materialized architectural shape, and a dimensioned structure. The architectural plans and the structural draft mainly convey 3D volumes or shapes which **require little knowledge of the opposite discipline** to be understood. Because of the **low level of disciplinary abstraction** used in the communication **little MIK** was needed. In these cases the **search space** for the overall shape of the building is **narrow** from the start of the collaboration.

Case one and two: expert architect, experienced teamwork, LP

These two cases are two smaller housing projects I did with two different architecture offices. The major part of the collaboration was identical to most of my projects as described above. These two projects contained however an interdisciplinary collaboration on a smaller part of the design where a problem occurred.

The communication on the problem was by telephone and fax (**quasi direct interpersonal contact**). The level of abstraction of the knowledge involved was low because the discussed problem was not complicated. A **range of different concrete structural design solutions** were evaluated together.

Within these two teams the **knowledge of the opposite discipline is large**. I have a good understanding of the architectural language because of my additional architectural education, and of the architect's preferences due to the many projects we did together. The architect on the other hand, has a lot of structural knowledge, partially gained through our collaboration (**interdisciplinary knowledge developed through experience**). Therefore we can well anticipate the problem of one another.

In these cases **little of the possessed MIK is shown in the communication**. Still an interdisciplinary design step is taken, because both actors possess sufficient MIK to be able to take certain **interdisciplinary design step on their own**. Of course there is the risk of **narrowing down the search space too soon**, when a design step is made without consulting the expert of the other discipline.

In these two cases the **search space** was **narrow** at the start and had to get wider to deal with the encountered problem.

Case three: expert architect, novel teamwork, LP

This case is a renovation project of a house. The architect is experienced, but it is the first time we work together. As in the two cases above, the project was presented to me **late in the design process**, and contained a design problem which involved interdisciplinary collaboration.

The main differences between this case and the cases above, lay in the teamwork. Because it was the first time we met, there was **more direct interpersonal contact** than in the previous cases: **face-to-face meetings** and telephone meetings. They were needed to understand better each other's way of working and desires concerning the project.

The project was presented to me through 2D plans for building approval and some 3D computer sketches. The architect explained her **architectural concept** and the intended expression (e.g. 'a shape like a table') of the project. In this way she stated the structural **question with a high level of abstraction**: it enabled me to understand which kind of structure I had to design for the architect (e.g. visible or hidden) and to anticipate the type of structural design solutions the architect preferred, if problems would occur.

Different structural design solutions were presented for the encountered design problem to the architect in the form of hand drawn sketches and computer calculation prints of structural models and dimensions. These solutions were structurally explained to the architect on a level of general **structural principles** (e.g. wind bracing) (**high level of abstraction**). After team evaluation a solution was chosen.

The **search space is bigger** than with an experienced teamwork, because it is unclear for both members in which area the desired design solution lays for the opposite member. Therefore more design possibilities are explored and presented to the other partner.

Case four: expert architect, novel teamwork, EP

This project was the second one I did with this experienced architect and the result of a won contest. The **collaboration started early in the design process**, in the preliminary phase. Interdisciplinary collaboration occurred during the design of a shed connecting different elements on the site. The project was presented to me in the form of **3D computer sketches** and the **architectural concept** (‘making it float’) was explained to me on the telephone. These sketches give a good feel of the project, but are not very detailed: there is even no information of the materials used, nor their dimensions (**search space large, high level of abstraction**). As Dark (1984) describes it, they serve more like a ‘conjecture’ of a design, to be evaluated by the different architectural criteria which include structural stability.

Unlike in most cases, the architect did not ask for a dimensioned structure, but for structural concept proposals as a guide for further design of the architectural shape. This **question with a high level of abstraction** enables more interdisciplinary creativity to take place than questions for a single concrete design solution.

For me, many structural models were possible, based on different structural principles (e.g. many small columns versus a few big columns). I made **hand drawn sketches of the different structural principles** (**search space large, high level of abstraction**) to see if there was one of them the architect preferred and e-mailed it to her. We decided to have a face-to-face meeting to solve this design problem, because **direct interpersonal contact** enables quick responses on posed questions -which instigates creativity- and diminishes the risk of miscommunication through instant feedback.

We discussed the architectural and the structural concept of the shed and decided they should be the same for the total length of the shed. (This meant many small columns as structural and architectural elements, crisscrossed in space as tree stems). In this discussion both actors require sufficient **knowledge of the opposite discipline** to comprehend the high level of abstraction of the proposed **conceptual design solutions**.

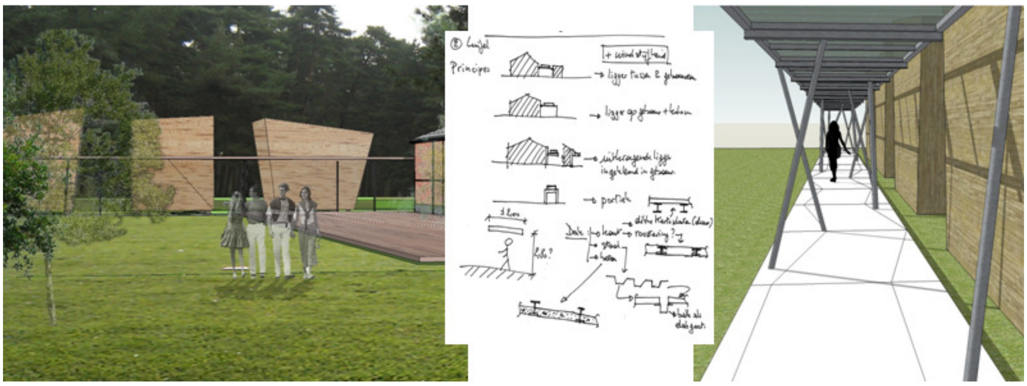

Figure 2 *copyright renderings: TEEMA-architecten*

Shed design: (left) first architectural ‘conjecture’; (middle) structural principles; (right) final design.

After this meeting, structural calculations were made to determine the minimum dimensions of the structural elements in different configurations. These findings were e-mailed to the architect who used these dimensions to check the visual expression of the shed. The architect designed then the final configuration.

Seminar: novice architect, novel teamwork, EP

This seminar represent 23 cases with students in their last master year of architecture. They have very little experience and it was the first time we worked together. Here I was involved **from the beginning of the design process**.

This seminar is not completed yet, but there are already some interesting findings. The students proposed their architectural ideas through very **basic** software and hardware **3D models, and 2D plans**. All of the communication happened during **face-to-face** meetings, where the students explained their **architectural concept**, or their search for a sound concept (**high level of abstraction**). In their explanations they often used **visual analogies of existing buildings** (e.g. 'We want to have our building to have a façade like this building').

At the very beginning of the design process, I could give very little structural input to the students, because the architectural information given, still enabled too many structural design solutions: **the collaboration was too early in the process**.

Conclusion on communication during interdisciplinary design

For architect and engineer to have a creative interdisciplinary collaboration it is important to start from a wide search space and to keep it wide as long as possible, while more input is gathered from the different disciplines. Narrowing down the search space too soon, can exclude some very creative design solutions.

Keeping this in mind, I can conclude by analyzing my own projects as structural engineer, that interdisciplinary design has the following characteristics on the level of communication:

1. **Direct interpersonal contact**: face-to-face meeting or even communication by telephone enables quick response on questions posed –essential to design as a team- and diminishes miscommunications through instant feedback.
2. **Collaboration early in the design process (but not too early)**: the search space is still wide for a maximum of interdisciplinary creativity.
3. **Knowledge of the opposite discipline**: this enriches the communication by using discipline dependent idioms with a high level of abstraction.
4. **Questions with a high level of abstraction**: in order to receive a wide range of design solutions from the opposite discipline, the question should not be restrictive (e.g. not asking for a dimension but for a structural concept). This helps keeping the search space wide.
5. **Answers with a range of design solutions instead of a single design solution**: this can be different concrete design solutions or conceptual design solutions (high level of abstraction). This keeps the search space wide while the design process evolves.
6. **Interdisciplinary knowledge can be developed through experience**: through the experience of personal building practice and interdisciplinary teamwork, knowledge of the opposite discipline can increase. Possession of this knowledge enables the single person to take an interdisciplinary design step alone. This can however involuntarily limit the search space when the expert is not consulted.

One of the main characteristics of interdisciplinary design, is the high level of abstraction in communication: this is the use of discipline depended concepts or principles. It implies that engineer and architect have to possess sufficient mutual interdisciplinary knowledge (MIK) for this communication to be successful. If we want to educate engineers and architect to design in an interdisciplinary (and not intradisciplinary) team this MIK should be taught. So the next question is: what should architects know about engineering, and engineers about architecture?

Acknowledgements

I would like to thank Fredrik Nilsson for the comments made, and the following architects for their cooperation: Hendrik Van Liedekerke, Karolien Vanmerhaeghe, Tom Van Mieghem, Gerrit Verbeeck and Edith Wouters.

References

Akin, Ö.: 2002, Variants in design cognition, in C. Eastman, M. McCracken and W. Newstetter (eds), Design Knowing and Learning Cognition in Design Education, Elsevier, Amsterdam, pp. 105–124.

Austin, S., Steele, J., Macmillan, S., Kirby, P., Spence, R.: 1999, Using training workshops to map interdisciplinary team working, Proceedings of Chartered Institute of Building Services, Engineers National Conference 1999, Harrogate, pp. 38-49.

Dark, J.: 1984, The Primary Generator and the Design Process, in N. Cross (ed.), Developments in Design Methodology, John Wiley & Sons, Chichester, pp. 175-189.

Engel, H. and Rapson, R.: 1967, Tragsysteme/Structure Systems, Deutsche Verlags-Anstalt, Stuttgart.

Fauconnier, G.: 1986, Algemene communicatietheorie, Martinus Nijhoff, Leiden.

Fruchter, R., Clayton, M., Krawinkler, H., Kunz, J., Teicholz, P.: 1996, Interdisciplinary communication medium for collaborative conceptual building design, Advances in Engineering Software, 25(2-3), pp. 89-101.

Lottaz, C., Stouffs, R., Smith, I.: 2000, Increasing Understanding During Collaboration Through Advanced Representations, Journal of Information Technology in Construction, 5, pp. 1—24.

Quanjel, E.M.C.J and Zeiler, W: 2007, Design Collaboration and Team Working, in M. Bauer and C. Lima (eds.), Information and Knowledge Mangement - Helping the Practitioner in Planning and Building. Proceedings of the CIB W102 3rd International Conference, Fraunhofer IRB Verlag Stuttgart, pp. 51-60.

Quanjel, E.M.C.J, Zeiler, W., Savanovic, P, Borsboom, W.A., Spoorenberg, H.: 2006, Integral Design Methodology for Collaborative Design of Sustainable Roofs, 23th International Conference on Passive and Low Energy Architecture, PLEA 2006. Conference Geneva. 6-9 September 2006.

Rosenman, M.A. and Gero, J.S.: 1996, Modelling multiple views of design objects in a collaborative CAD environment, Computer-Aided Design, 99, pp.193-205.

Rosenman, M. A., Smith, G., Ding, L., Marchant, D. and Maher, M. L.: 2005, Multidisciplinary Design in Virtual Worlds, in B. Martens and A. Brown (eds), Computer Aided Architectural Design Futures, Springer, Dordrecht, pp.433-442.

Steele, J., Macmillan, S., Austin, S., Kirby, P., Spence, R.: 2000, An internet-based system to support interdisciplinary and inter-organisational collaborative conceptual design,. Procs of CIBSE National Conference, CIBSE2000, Dublin.

Stouffs, R.: 2000, Resolving issues of information and communication in a building project, in G. Gudnason (ed.), Construction Information Technology, vol. 2, Icelandic Building Research Institute, Reykjavik, pp. 895-906.

Strauven, I. and Ney, L.: 2005, Ney & Partners Freedom of form finding,: Vlaams Architectuurinstituut, Antwerpen.

Tunçer B., Stouffs R. and Sariyildiz I.S.: 2000, Collaborative information structures: educational and research experiences, COOP 2000 workshop proceedings: Analysing and Modelling Collective Design, INRIA, Rocquencourt, pp. 20-28.

Zeiler, W., Quanjel, E.M.C.J. : 2007, Integral Design methodology for Industrial Collaboration Design of Sustainable Industrial Flexible Demountable buildings, in M. Bauer and C. Lima (eds.), CIB W102 3rd International Conference Information and Knowledge Mangement - Helping the Practitioner in Planning and Building, Fraunhofer-Informationszentrum Raum und Bau IRB, Stuttgart, pp. 1-10.